Technical Note: Explicit Context Variables for Context-Conditioned Linear Systems

Motivation

Modern neural networks typically infer context implicitly from hidden activations. An alternative is to represent context explicitly as a collection of persistent state variables that condition a family of learned local linear predictors.

Rather than learning every aspect of behavior from data alone, computational responsibilities are divided between explicit context mechanisms and learned computation.

Multiple Forms of Context

Different forms of context operate over different time scales.

Behavioral context

- Finite automaton state.
- Search, approach, manipulation, escape, rest, exploration.
- Goal completion and task phase.

Temporal context

- Memory of previous events.
- Time since last reward.
- Time since object detection.
- Sequence history.

Clock context

- Internal circadian or ultradian clocks.
- Time of day.
- Seasonal phase.
- Anticipation of regularly occurring events.

Many biological behaviors depend strongly on internal clocks rather than immediate sensory input alone.

Spatial and navigational context

- Current location.
- Estimated heading.
- Landmark relationships.
- Position of the sun or stars.
- Home direction.
- Environmental map.

Navigation often depends on persistent internal state combined with sensory observations rather than purely reactive processing.

Physiological context

- Hunger.
- Fatigue.
- Stress.
- Energy reserves.
- Hormonal state.

The same sensory input may produce entirely different actions depending upon physiological state.

Hysteresis Context

Context variables should not necessarily change immediately when inputs cross decision boundaries.

Introducing hysteresis provides stable behavioral commitment by allowing context transitions to depend upon recent history.

Advantages include:

- Reduced oscillation between modes.
- Increased robustness to noisy observations.
- Stable execution of behaviors.
- Smooth transitions between contexts.

Context-Conditioned Linear Computation

The learned computation becomes

Output = Local Linear Predictor(Context, Input)

where context may combine:

- Behavioral state.
- Temporal memory.
- Internal clocks.
- Spatial state.
- Physiological variables.
- Geometric routing variables (e.g. Atlas or LSH context).

The context determines which local computation is appropriate while the linear predictor performs the detailed estimation or control.

Biological Inspiration

From a neuroethological perspective, many animals appear to organize behavior around persistent internal states rather than purely reactive stimulus-response mappings.

Examples include:

- Feeding versus exploration.
- Escape versus investigation.
- Courtship versus foraging.
- Day versus night activity.
- Homing versus local exploration.

These contexts may remain active for seconds, hours, or even seasons, while learned sensorimotor computation adapts continuously within each mode.

Rather than viewing intelligence as a single continuous computation, it may be useful to view it as **context selecting computation**.

Research Questions

- Which context variables should be innate and which should be learned?
- Can finite automata, clocks and navigation variables be jointly optimized with learned local predictors?
- Can hysteresis improve robustness and reduce unstable context switching?
- Can explicit context reduce the burden on recurrent neural networks?
- Can context variables improve interpretability while preserving learning performance?

Summary

Explicit context may represent a missing abstraction in many neural architectures. Finite automata provide behavioral modes, temporal variables provide memory, internal clocks provide anticipation, spatial variables provide navigational state, and hysteresis provides robust transitions. Together these persistent context variables select families of learned local linear computations. This hybrid architecture provides a possible bridge between switched linear systems, modern neural networks, robotics, and the state-dependent organization of behavior studied in neuroethology.